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IDENTIFICATION OF THE DAMAGE IN WOVEN COMPOSITES BASED ON ACOUSTIC EMISSION CLUSTER ANALYSIS

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ABSTRACT

Understanding the failure mechanisms in textile composites based on acoustic emission (AE) signals is a challenging task. In the present work, unsupervised cluster analysis is performed on the AE data registered during tensile tests on 2D and 3D woven carbon and glass fibre/epoxy composites. The analysis is based on the k-means++ algorithm and principal component analysis. Peak amplitude and frequency features – peak frequency for 2D woven composites and frequency centroid for 3D woven composites – were found to be dominant in cluster analysis. Cluster bounds were identified for all composite types. These bounds do not differ with a reinforcement type, but do differ for glass and carbon reinforced composites. These bounds can be used as a starting point for AE analysis of other carbon or glass fibre/epoxy composites (Figure 1)

The statistics of high frequency AE events in carbon reinforced composites are compared with the estimates obtained from a fibre bundle model based on Weibull fibre strength statistics. The number of AE events agrees well with the number of groups of carbon fibres that fail simultaneously. This finding may provide a new way to explain why the Weibull distribution predicts much more fibre breaks than measured by AE.

AE events registered during tensile loading of a plain weave glass/epoxy laminate are correlated to actual damage, which is observed optically. Cracks in the transparent laminate, visible in the backlight images, are counted during the tensile test. Transversal and longitudinal cracks in the yarns and localised delaminations are distinguished. AE events are classified according to the amplitude and peak frequency of the signal into low frequency – low amplitude, low frequency – high amplitude and high frequency clusters. The latter (high frequency) AE events are assumed to be connected to the fibre breakage. The cumulative number of transversal and longitudinal matrix cracks corresponds well to the number of AE events in the low frequency – high amplitude cluster, and the number of delaminations – with low frequency – high amplitude cluster. The study validates use of cluster analysis of AE for identification of damage models in woven glass fibre reinforced laminates.

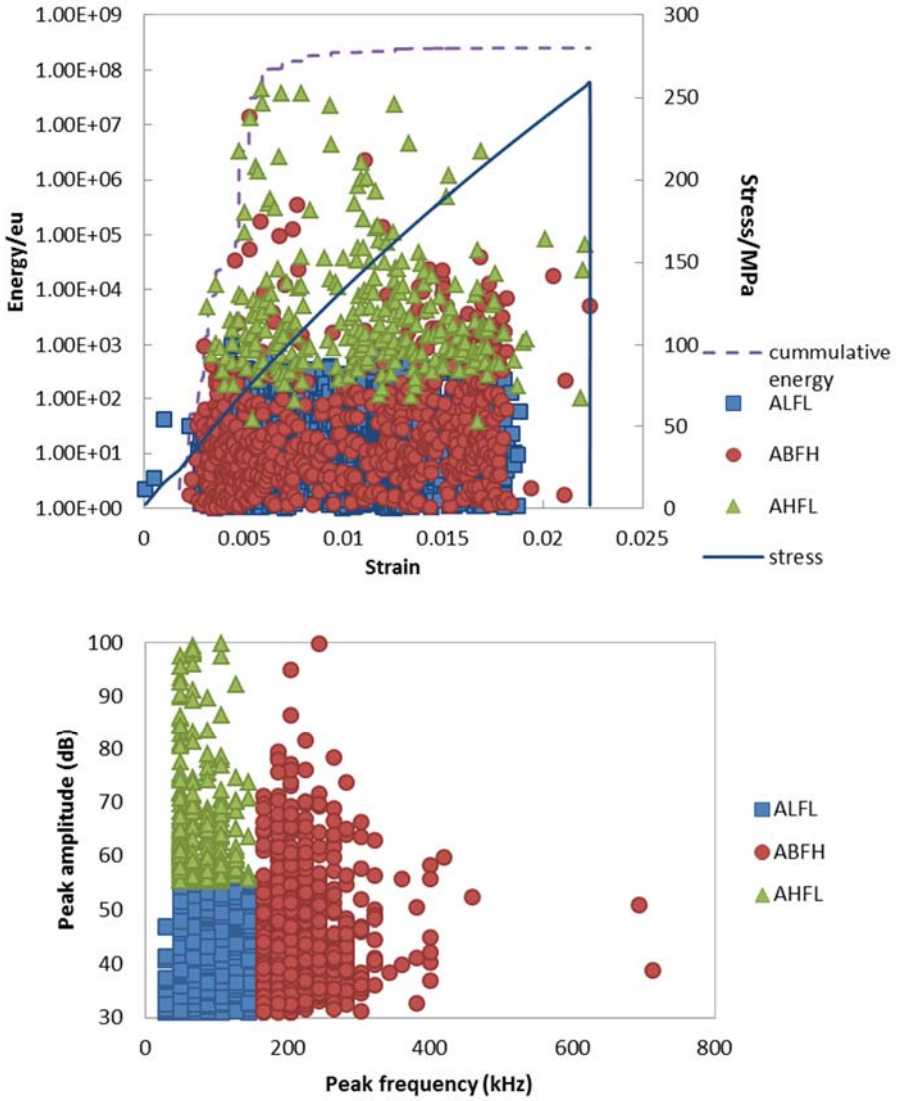

Figure 1: Cluster analysis for a glass fibre 2D woven composites

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